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Energy Savings and Pollution Prevention Benefits of Solar Heat Gain Standards in the International Energy Conservation Code

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Abstract

The International Energy Conservation Code (IECC), published by the International Code Council, the code development organization of building code officials, contains new provisions that save energy and reduce air pollution emissions. Its most significant new provision is a prescriptive standard for solar heat gain control in windows in warmer climate zones. Because solar heat gain through windows is one of the largest components of residential cooling loads, this standard reduces cooling loads dramatically, which in turn reduces electricity consumption, utility bills, and powerplant pollution emissions. It can also reduce the size of cooling equipment, a capital cost saving that can offset increased costs for the higher-performance windows needed to meet the standard.

This paper documents the potential energy efficiency, dollar, and pollution reduction benefits of the IECC's solar heat gain standard. Using the RESFEN model developed at Lawrence Berkeley National Laboratory, we simulated a typical new home in ten southern states that would be affected the new IECC solar heat gain standard. Our analysis found that in these ten states, adoption of the IECC in its first year could save 400 million kWh, \$ 38 million in electric bills, and 233 MW of peak electricity generating capacity. The cumulative savings from these homes in year 20 would rise to 80 billion kWh, \$7.6 billion in electricity bills, and 4,660 Megawatts of generating capacity. In year twenty, the electric energy savings would also prevent the emission of 20,000 tons of NOx and over 1.5 million tons of carbon equivalent.

Extrapolating the calculations in this paper to include other states with significant cooling load reductions from the IECC leads us to believe peak savings from new construction will total 300MW annually. Given that the window replacement and remodeling market is slightly larger than the new construction market (and here the baseline is poorer performing single glazing), leads to the conclusion that savings which include the remodeling and replacement market should exceed 600MW annually. This would eliminate the need to build two average sized 300MW power plants every year. Additional, similar savings could also be expected from applying this technology to windows in commercial buildings, although we have not accounted for these savings in these estimates.

Introduction

Under the provisions of the Energy Policy Act of 1992, states are required to consider adoption of the Model Energy Code (MEC) of the Council of American Building Officials, and of any successor codes that the U.S. Department of Energy determines are more stringent than the MEC. As of 1998, the MEC has been superseded by the IECC in a coordinated plan developed by the International Code Council. The IECC is identical in format and mostly in content to the MEC, though it contains some changes stemming from the ICC code development process subsequent to the 1995 version of the MEC.

The greatest effect on stringency in the IECC stems from the inclusion of a Solar Heat Gain Coefficient (SHGC) standard of 0.4 or less, which applies in climate zones with 3500 heating degree days or less. The SHGC value must be certified by the National Fenestration Rating Council (NFRC); in NFRC rating procedures, SHGC is the percentage of solar heat gain transmitted through the fenestration product as a whole. A SHGC of 1 means that all solar heat passes through the window—an impossibility under normal conditions. SHGC values can range from around .8 to .2 or less depending on coatings, tintings, frame area relative to glass areas, and other factors.

Typical SHGC values for representative window types are:

• Single-pane, metal frame, clear glass	.75
• Double-pane, metal frame, clear glass	.66
• Double-pane, metal frame, bronze tint	.55
• Double-pane, wood-vinyl frame, clear glass	.55
• Double-pane, metal frame, low solar gain low-e coating	.37
• Double-pane, wood-vinyl frame, low-solar-gain low-e coating	.31

Source: *ASHRAE HandBook of Fundamentals, 1997.*

The lowest SHGC values are typically found in windows with low-e coatings formulated to reduce solar gains. Tinted glass can also reduce SHGC values, but to reach a .4 level, the glass would typically be darker than most consumers prefer, sacrificing a lot of visible light for the amount of solar gain reduced.

The original low-e coatings brought to market in the 1980s were formulated primarily for heating climates; they reduced heat loss through the window, but allowed most solar gain to enter the house. More recent low-e coatings allow windows to reduce both heat loss and heat gain. As more and more products have come on the market using this type of coated glazing, low-solar-gain low-e windows have become an effective means of reducing solar heat gain and the cooling energy use that comes with it.

The IECC allows flexibility in meeting the .4 SHGC standard, by allowing it to be met through NFRC-rated window products, fixed external shading, or a combination. Thus, windows meeting the .4 SHGC standard are just one way to comply. However, many home builders, especially larger "production" may prefer to simply alter their window specifications than to alter the basic home design to provide the necessary external shading. For example, providing the extended eaves necessary to provide full shading for the windows may increase construction costs more than upgrading the windows themselves.

As states adopt the IECC in climate zones affected by the SHGC standard, they will want to evaluate the potential benefits of the IECC in reducing consumer energy bills, reducing air pollution emissions, and reducing the growth in peak electric generating capacity. This paper provides an analysis of the potential benefits in these areas, for state and local governments and others to use in considering IECC adoption as well as other initiatives to promote the use of high-performance fenestration products.

Methodology

Calculation Method: the RESFEN model

Our approach was to calculate the potential effect of low-solar-gain low-e windows on reducing annual heating and cooling energy use in new homes in the 10 states most affected by the IECC's SHGC standard. The core calculations were made with RESFEN, an LBNL-developed simulation model specially designed for very accurate calculation of the effect of different window types on residential energy use.

Based on a DOE-2 simulation engine, RESFEN is able to achieve high accuracy in its energy use calculations. DOE-2 has been validated by several studies (Sullivan 1998), including its ability to simulate solar heat gain's impact on annual energy use. These studies show very close agreement between measured data from real buildings and simulation results from DOE-2 based programs such as RESFEN. The user interface contains a library of window specifications, allowing more than 30 window type selections, and can accept other window data libraries or user defined inputs for further variety. While a default house prototype is provided automatically, the interface allows the user to choose the location, energy prices, square footage, number of stories, foundation type, new vs existing home, framing type, heating/cooling system type, total window area, window area by orientation, and various external and internal shading options.

Baseline window types used in this analysis were either single-pane clear metal-frame windows in the warmest areas, such as Miami and Houston, or double-pane clear metal-frame windows in the more moderate areas like Albuquerque or Atlanta. A table showing which baseline window was used in each case is show in the Appendix. These baselines were estimated using building practice data obtained from consultations with industry sources and energy experts in affected states. The IECC-compliant windows were double-pane, wood or vinyl frame units with low-solar-gain low-e coatings; these were deemed to be the most likely window type sold as a compliance option.

As in most simulation-based analyses, the selection of modeling assumptions is important if not central to the accuracy of the results. Because fenestration performance is affected by external shading, internal shading, the presence of insect screens, and other factors, it was important to make assumptions that represent a realistic approximation of field conditions. Fortunately, this task had recently been undertaken in a consensus process sponsored by the National Fenestration Rating Council's Annual Energy Performance Subcommittee. The result of their effort, published by ASHRAE (Arasteh 2000), provides specific assumptions for exterior shading, adjacent buildings, interior shading, and such factors as screens, dirt, and trees. We believe these assumptions are realistic, even conservative, especially for a new construction environment.

RESFEN holds constant other assumptions regarding envelope efficiency and heating and cooling system efficiency. For new homes, envelope and HVAC systems are defaulted to comply with the 1995 MEC. This feature allows straightforward analysis of the effect of windows on annual energy use, within the context of a building code adoption study. Since the prototype house is deemed to comply with the 1995 MEC, and since the SHGC standard is the only significant stringency change from the 1995 MEC to the IECC, RESFEN is well-suited for assessing the potential impact of the IECC in states affected by the SHGC standard.

In other analyses related to the impact of building codes (Norland 1998), we have included several aspects of residential buildings, such as insulation in various envelope components, mechanical system types and efficiencies, and other factors in addition to windows. This has required a much more complex analytical approach, with multiple house prototypes and many more model runs. In this case, however, because the IECC's stringency changes affect windows almost exclusively, we were evaluating only the window-related aspects of energy use. This fact enabled us to simplify the analysis, fixing all aspects of a single prototype home except for the window type.

Analysis of RESFEN Output

The key RESFEN outputs used in this analysis are annual heating energy use, annual cooling energy use, annual heating energy cost, annual cooling energy cost, and impact on peak electric demand for cooling. These outputs were transferred to a spreadsheet for comparison purposes; the spreadsheet was designed to compare baseline window types with windows meeting the IECC SHGC standard. The spreadsheet calculates total savings in kWh, total cost savings in dollars, and total peak electric demand reductions in kW for each prototype house and location. It also sums the impacts by state and for the 10-state study area overall.

One or two cities were selected in each state for analysis purposes as follows:

- Charleston, South Carolina
- Atlanta, Georgia
- Jacksonville, Florida
- Miami, Florida
- Birmingham, Alabama (also used for Mississippi)
- Lake Charles, Louisiana
- Houston, Texas

- Dallas, Texas
- Albuquerque, New Mexico
- Phoenix, Arizona
- Las Vegas, Nevada

The ten states represented by these cities are those whose land area or housing starts fall entirely or mostly in the sub-3500 heating degree-day zone affected by the IECC SHGC standard. Other states that are partially affected, such as North Carolina, Arkansas, and Oklahoma, were not included in this analysis.

For each of the affected states, we multiplied the energy, dollar, and peak savings calculations for the prototype house by the number of housing starts, as reported by the U.S. Bureau of the Census (Census 2000). The energy savings totals were then multiplied by emission factors obtained from U.S DOE and U.S EPA sources (DOE, EPA) to estimate pollution emission reductions. State totals were then summed to yield grand totals for the 10-state study area.

Where multiple cities were used in the same state, we allocated housing starts equally to each city, and then summed and/or averaged results as needed to estimate totals for the state. In this analysis, two cities each were used in Florida and Texas, to account for the wide range of climate zones within those states. In other states a single city was deemed adequate to estimate results for the state.

Sensitivity Analysis

Because such factors as glass area, glass orientation, and shading could affect this analysis, we conducted sensitivity analyses to test the potential effect of variations in these factors on the results of our analysis. We selected three cities (Miami, Dallas, and Phoenix), and varied the prototype house in the following ways:

- Increased window area from 15% to 20% of floor area
- Decreased southern and western glass areas from 75 square feet to 30 square feet each
- Increased external shading from typical to fully shaded on all orientations
- Decreased external shading from typical to none on all orientations

Results

The energy, dollar, and peak demand results of our analysis are summarized in Tables 1 and 2. Where multiple cities were used in a state, city-level results were summed and/or averaged to yield state totals.

Table 1
Annual Energy, Dollar, and Demand Savings Per Home

State	Kwh	Dollars	kW

South Carolina	542	$44	0.47
Georgia	463	$37	0.38
Florida	1437	$111	0.68
Alabama	814	$81	0.54
Mississippi	1072	$81	0.54
Louisiana	1378	$108	0.38
Texas	891	$98	0.61
New Mexico	1096	$103	0.39
Arizona	1173	$138	0.65
Nevada	1416	$96	0.6

Table 2
State Total Energy, Dollar, and Demand Savings
Annual Impacts for Each Year's New Home Production

State	Housing Starts	KWh	Dollars	kW
South Carolina	24,467	13,261,114	$1,088,537	11,499
Georgia	67,879	31,427,977	$2,521,705	25,794
Florida	97,889	140,617,549	$10,873,021	66,565
Alabama	14,655	1,192,477	$1,192,477	7,914
Mississippi	8,671	9,295,312	$705,559	4,682
Louisiana	13,875	19,119,750	$1,491,701	5,273
Texas	99,831	88,949,421	$9,818,379	60,897
New Mexico	9,217	10,101,832	$949,535	3,595
Arizona	50,540	59,283,420	$6,994,736	32,851
Nevada	24,445	34,614,120	$2,353,565	14,667
TOTALS	411,469	407,862,972	$37,989,215	233,736

These tables show that just one feature of the IECC—its solar heat gain standard for windows—contains major energy, dollar, and electric capacity savings for these ten states. Their combined 411,000 housing starts account for almost half the single-family starts in the entire U.S. market. For each year's housing production in these states, consumers would save more than 400 million kilowatthours, about $38 million in electric bills, and 233 Megawatts of generating capacity.

Over twenty years, about eight million homes will be built in these states. The cumulative savings from these homes in year 20 would rise to 80 billion kWh, $7.6 billion in electricity bills, and 4,660 Megawatts of generating capacity. The electricity savings in year 20 for all the homes built with these windows are just under one percent of total U.S. residential energy use; the capacity savings would be equivalent to fifty or more peaking combustion turbines.

The electricity saved by the IECC would also prevent substantial amounts of air pollution and greenhouse gas emissions. In year twenty, it would prevent the emissions of 1.5 million tons of carbon equivalent and 20,000 tons of nitrogen oxides.

On a life-cycle basis, over a 30-year period total savings would cumulate to 186 billion kWh and $18 billion in energy bill savings.

For the individual homeowner, electric bill savings would range from about 9% to more than 20% of total heating and cooling costs. The lower end of the savings range tends to occur in the cooler parts of the ten-state region, where the solar heat gain reduction benefit is less than in the hotter areas. Homeowners would also experience benefits in the form of improved comfort and usability of their homes. Solar control measures would make areas of the home with high sun exposure more comfortable in hotter parts of the day. Low-e coatings would also reduce fading and deterioration of interior fabrics and furnishings, extending their life and preserving their value.

Comparison to Field Monitoring Studies

Several field tests have been carried out in various southern climates with the objective of measuring the peak demand and energy savings from spectrally selective low-e windows. These projects either involve side by side studies on identical houses, window only replacements, or determining window effects from a comparison of monitored to simulated data for the test period. The results, summarized in the table below, show peak demand and cooling savings consistent with the simulations presented earlier. Peak savings measured vary significantly from 0.2kW to 1kW. Peak savings from simulation studies presented earlier vary from 0.39 to 0.65 kW. This larger variation in the measured data is attributable mainly to house size variations, non-equal distribution of window areas by orientation, and other strategies taken to reduce peak demand. It should be noted that in the FL and AZ houses, shading strategies were used to effectively minimize cooling load impacts on windows; without such strategies (as is typical in production building), cooling impacts from windows (and savings from high performance windows) would have been greater.

Project & Location	Monitored Peak Reduction	Monitored Cooling Energy Reduction	House Size	Glass Area (% floor area)
Cardinal IG; Sacramento CA	1.0 kW (30%)	26%	1854 sf	329 sf (18%)
FSEC/FPC Melbourne FL	0.63 kW (19%)	15%	2122 sf	265 (12%)

FSEC Lakeland FL	0.75 kW (16%)	19%	2425 sf	384 sf (16%)
NREL- Tucson AZ	0.2 kW (7%)	13%	1170	272 (23%)
NREL – Phoenix AZ	1 kW (19%)	12%	1650	274 (16%)

The following paragraphs provide a short summary of each project.

Cardinal IG bought two identical houses in Rosemead CA (a Sacramento suburb) and commissioned the two houses to ensure that their thermal performance and HVAC characteristics were as identical as possible (Larsen 2000). The only differences between the two houses are the glazings used in the windows; one has spectrally selective low-e double glazing and the other has clear double glazing. The windows in both houses use the same vinyl frames. The 30% peak electrical demand savings and the 26% cooling energy use savings shown are for an average of two weeks in September. These savings are slightly larger than average since this house has slightly more west facing glass than typical. (Of the 329 sf of glass, 186 sf or 56% face west while there are 40 sf on the south and north and 63 sf on the east.)

In conjunction with Florida Power Corporation, Florida Solar Energy Center (FSEC) performed side-by-side testing of two identical houses (Melbourne FL). The only differences between the two houses are the windows; one has spectrally selective low-e double glazing and a thermally broken aluminum frame while the control house has clear single glazing and a conventional aluminum frame. The duct systems, air tightness, and air conditioning system efficiencies in both houses were measured and were uniform between both houses. Physically, the houses were identical, their orientation was the same, and site characteristics were very similar. The 19% peak electrical demand savings (0.63 kW) savings and the 15% cooling energy use savings shown are based on monitoring over a 17 day period in the summer of 1999. A detailed simulation of the house predicted peak savings consistent with measured results. The window areas are 45% east facing, 24% west, 26% north, and 5% south; this slight skewing of windows towards the east and away from the south and west helps slightly reduce peak impacts from windows.

A second FSEC project (Lakeland FL) shows the potential peak load reductions and annual energy savings possible in central Florida residences equipped with state-of-the-art technologies (Parker at. Al. 1998). FSEC built and monitored two similar houses: (1) a control house typical of new construction in central FL and (2) an advanced house with spectrally selective low-e windows, a reflective roof, an interior duct system, wider overhangs, efficient appliances and lighting, a high efficiency HVAC system, and a roof integrated PV system. The homes were built and tested to ensure uniform operating characteristics. Due to the cumulative effect of all these features, the electrical demand of the advanced house during the utility's peak (without accounting for the electricity supplied by the PV system) was 86% less than that of the control home. Detailed monitored data was used to develop and validate simulation models of the houses. These models were then used to isolate the savings from individual components such as windows (includes overhang effects): a 16% (or 0.75 kW) reduction in peak electrical demand and a 19% reduction in cooling energy use. The windows in the control house were single glazed aluminum-framed windows while the advanced windows were spectrally selective low-e double glazed vinyl-framed windows. The window areas are 13% east facing, 13% west, 40% north, and 34% south; this skewing of windows towards the north helps reduce peak and cooling energy impacts from windows.

In Tucson AZ, NREL researchers monitored a 1170 sf residence with 272 sf of window area and compared the monitored results to a detailed simulation model in order to ascertain the impacts of high performance windows and solar shading strategies. The combination of higher performance windows (vinyl framed spectrally selective low-e) and solar shading compared to standard windows (vinyl framed, dual clear) and no shading was found to reduce peak demand by 0.4 kW or 14% . The impact of windows alone on peak demand was 0.2kW or 7% and on cooling energy alone was 13%. Note that in this house, while the fraction of glazed area to floor area is higher than typical, most of the glazing is heavily shaded and faces east. In buildings without such shading, and/or with more west facing glass, the percentage impact of high performance spectrally selective low-e coatings will be much greater. In addition, the glass in the patio doors was standard low-e which has a slightly higher SHGC than spectrally selective low-e.

As part of NREL's Building America program, two new and identical production homes were built and monitored in Phoenix to understand the potentials for energy and peak demand reductions from energy efficiency upgrades. These 1650 sf homes had 274 sf of windows (16% of floor area). A control home represented standard construction while an advanced house included spectrally selective windows and improved HVAC and duct systems. The advanced home reduced energy use and peak demand by over 40%. In order to isolate the effects of just the windows, the clear double glazing in the control home was replaced with spectrally selective low-e glazing. The standard aluminum frames remained. Peak power reductions from just the window change out alone is approximately 1kw (of 5.2 kw) or 19%; cooling energy savings from the windows upgrades are 12%.

Field tests from the MoWiTT calibrated test chambers have also provided conclusive evidence of the ability of spectrally selective glazings to reduce solar heat gain loads (Klems 1995). These test results validate the reported Solar Heat Gain Coefficients for commercially available spectrally selective low-e glazings.

Sensitivity Analysis

We looked at alternative design options in the prototype homes in Miami, Dallas, and Phoenix to test the effects of changes in window area, window shading, and window orientation. These cities represent the hot/humid, mixed climate, and hot-dry climate zones in the ten-state region.

The basic prototype house used in the RESFEN analysis has 300 square feet of window area, which is 15% of conditioned floor area. It has equal amounts of window area on each orientation. The shading assumption uses the "typical" configuration in RESFEN, which includes a one-foot overhang, partial shading from adjacent objects such as buildings or trees, and partial interior shading (Arasteh 2000).
These shading assumptions were worked out in an extended peer process among researchers and fenestration industry stakeholders, and represent a conservative set of assumptions. It is thus unlikely that field conditions will contain more shading on average than that assumed in the base house. In fact, the opposite may be more likely, especially in large production building situations where trees are rare, and architectural shading is typically minimal. Where shading is minimal, the savings from low-solar-gain windows could be 60-70% greater than the base analysis.

We believe the 15% glass area assumption for the base house is also conservative. Field studies in Florida and California indicate that Sunbelt new construction produces homes with 15-20% window area as a percentage of floor area.

The four alternatives produced changes in energy savings as follows (percentages refer to changes in total heating and cooling costs; e.g. if savings changed from 1000 kWh to 800 kWh, this is reported as a 20% drop in savings):

- **Increased window area from 15% to 20% of floor area**—Increased savings by 29% in Miami, 39% in Dallas, and 36% in Phoenix
- **Decreased southern and western glass areas from 75 square feet to 30 square feet each**—Reduced savings by 7% in Miami, increased savings by 3% in Dallas, reduced savings by 9% in Phoenix
- **Increased shading from typical to fully shaded on all orientations**—Decreased savings by 28% in Miami, 16% in Dallas, and 28% in Phoenix
- **Decreased external shading from typical to none on all orientations**—Increased savings by 61% in Miami, 72% in Dallas, and 69% in Phoenix.

A composite result for these four alternatives, calculated by averaging the savings for the four options in each city, yields an increase of savings of 14% in Miami, 24% in Dallas, and 17% in Phoenix. While these four alternatives do not necessarily capture the range of field conditions, the fact that in the aggregate they tend to increase savings estimates indicates that our basic analysis tends to be conservative, and that real world impacts may quite likely be greater. Given the likelihood that typical building practice in the sunbelt has higher glass area and less shading than in our prototype home, we believe our analysis is at the lower end of likely impacts in the field.

Implementation Issues

Realizing the potential benefits of the IECC will require adaptations in the building industry, especially in measures taken to reduce solar heat gain in compliance with the

IECC standard. The IECC permits compliance with the SHGC standard with NFRC-rated window products meeting the 0.4 SHGC standard, or with permanent exterior shading that achieves the same performance. Solar-screen products, which can be attached to the exterior of windows, aftermarket window films, or architectural shading can be used to achieve the needed solar heat gain reduction. In the city of Austin, Texas, which has a solar heat gain reduction requirement similar to the IECC, solar screen products have been popular solutions for code compliance.

Market forces will decide which technologies are used for code compliance. For some builders, a simple upgrade in window specifications would suffice. Others may prefer aftermarket products, or to design in shading via wider eaves or other fixed shading. Low-solar-gain low-e windows are relatively new to these ten states, partly because the original low-e products used high-gain products more suited to heating-dominated climates. Market research data shows that low-e products have achieved 50% market penetration in the coldest parts of the U.S.; in the deep South, however, they are well under 10% of the market (Eto et al).

It is also true that the overall severity of weather as measured by indoor-outdoor temperature differences is lower in these southern states, which has made energy efficiency less of a focus. Recently, however, the need to reduce electricity use has increased, due in part to concerns about air pollution and climate change. That puts a new premium on the value of solar heat gain control. The increasing availability of low-solar-gain window products can be an effective solution to this challenge. NFRC's product directory shows almost 15,000 products that meet the IECC's 0.4 SHGC standard (NFRC 2000).

As with many energy-efficiency policies, there is concern about the potential cost of the improvements needed to meet the IECC requirements. This issue raises the importance of whole-building analysis in designing IECC compliance solutions. This is especially true of the interaction between window performance and HVAC system sizing. Because low-solar-gain windows are particularly effective at reducing peak cooling loads, they can allow cooling equipment to be sized at lower tonnage. This not only reduces the capital cost of the equipment, but can also improve the efficiency of the cooling system by reducing its cycling losses and part-load operation.

In the city of Austin, the experience has been that improved window performance has reduced air conditioner sizing by ½ to a full ton of capacity. The savings on the equipment generally offset upgrades to windows. DOE-2 validation studies (Sullivan 1998) also tend to support this finding. So it may be that meeting the IECC requirements, if done intelligently, can realize significant energy savings at little or no net capital cost.

Conclusions

This paper shows that the IECC's solar heat gain control provision can provide major energy, dollar, and pollution savings for ten Sunbelt states. Its major conclusions are:

- Over the next twenty years, using low-solar-gain windows in new construction, such as those required by the IECC, would save about one percent of total U.S. electricity usage.
- Over twenty years, the cumulative savings from these homes would rise to $7.6 billion.
- In year twenty, the saved electricity would prevent the emission of 20,000 tons of NOx and 1.5 million tons of carbon equivalent.

These savings are based on a rigorous analysis using the RESFEN simulation model. Its assumptions regarding real-world effects of shading and other moderating influences on window performance were worked out in an extending peer process in the National Fenestration Rating Council. Its results have been supported by field monitoring studies in Florida, one the target states. We therefore have a high degree of confidence that these numbers are real.

While realizing the benefits of the IECC requires addressing a number of implementation issues, we believe these are manageable and certainly worth the effort given the magnitude of the benefits.

Extrapolating the calculations in this paper to include other states with significant cooling load reductions from the IECC leads us to believe peak savings from new construction will total 300MW annually. Given that the window replacement and remodeling market is slightly larger than the new construction market (and here the baseline is poorer performing single glazing), leads to the conclusion that savings which include the remodeling and replacement market should exceed 600MW annually. This would eliminate the need to build two average sized 300MW power plants every year. Additional, similar savings could also be expected from applying this technology to windows in commercial buildings, although we have not accounted for these savings in these estimates.

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APPENDIX

Baseline and IECC-Compliant Window Specifications

	Baseline Window			IECC Window		
	Frame/Panes	SHGC	U-Factor	Frame/panes	SHGC	U-Factor
South Carolina	Wood/vinyl/2	0.56	0.49	Wood/vinyl/2	0.3	0.32
Georgia	Wood/vinyl/2	0.56	0.49	Wood/vinyl/2	0.3	0.32
Florida/Miami	Aluminum/1	0.76	1.25	Aluminum/2	0.38	0.6
Fl/Jacksonville	Aluminum/2	0.68	0.79	Aluminum/2	0.38	0.6
Alabama	Aluminum/2	0.68	0.79	Aluminum/2	0.3	0.32
Mississippi	Aluminum/2	0.68	0.79	Aluminum/2	0.3	0.32
Louisiana	Aluminum/1	0.76	1.25	Aluminum/2	0.38	0.6
Texas/Houston	Aluminum/2	0.68	0.79	Aluminum/2	0.38	0.6
Texas/Dallas	Aluminum/2	0.68	0.79	Aluminum/2	0.38	0.6
New Mexico	Aluminum/2	0.68	0.79	Aluminum/2	0.3	0.32
Arizona	Aluminum/2	0.68	0.79	Aluminum/2	0.38	0.6
Nevada	Aluminum/2	0.68	0.79	Aluminum/2	0.3	0.32